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REAL TIME MONITORING OF SUPPLY CHAIN MANAGEMENT NETWORK

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ABSTRACT:

The organizations that produce, distribute, handle or sell various goods are continuously searching for ways to increase profits, minimize operational costs and reduce wastage in order to accomplish a sustainable supply chain competitive advantage in terms of cost and other important factors. Among other optimizations in the process, Radio Frequency Identification (RFID) and WSN are increasingly being used in place of the more traditional barcode technology. RFID is used for real-time tracking and identification of people, animals, and items without human intervention. It can scan multiple and moving items at once through human body and non-metallic materials. Xbee (Zigbee) wireless communication network is easy to integrate with RFID-WSN system. It is able to increase the communication range as well as measure environmental parameters. This system provides smart identification of items on real time basis at a single control platform. It gives complete picture of items features and environmental constraints like temperature and humidity etc. Efficiency of this structure is higher in terms of accuracy, speed, quality and flexibility of operation.

1. INTRODUCTION:

Supply chain management (SCM) is the effective control of the movement of goods, finance, and provision of amenities. It includes the transaction of raw materials storage, inventory in process and finished items produce from initial stage to the final point where it is to be used. SCM cycle begins by the flow of raw materials from storage followed by manufacturing, warehousing, and retailer; finally, product sells to the customer [1-2] as shown in Fig 1.1.

Fig. 1.1. Supply Chain Management (SCM) Cycle

Aim of every SCM is to reduce operational cost, minimize wastage and increase profit. It can be achieved by real-time flow of information, product, and funds.The real-time information is the backbone of every supply chain. It needs an advance auto-ID technology to monitor and control.

2. AUTO-ID TECHNOLOGY:

The automatic identification and data capture (AIDC) technologies used for automatically identifying objects, data collection and to transmit that data directly into computer systems without human intervention [3]. AIDC include the following technologies such as bar codes, biometrics, Smart Cards, Optical Character Recognition (OCR) and Radio Frequency Identification (RFID) [4] as shown in Fig 1.2.

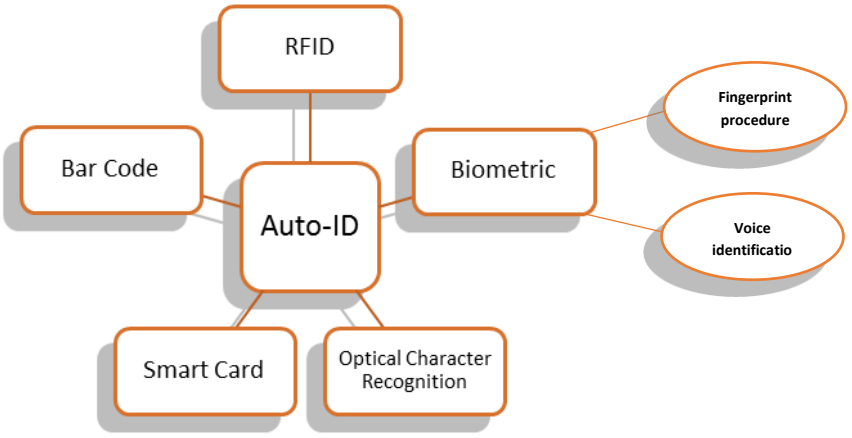

Figure 1.2. Important Auto-ID technologies [3]

Automatic identification (Auto-ID) technologies are very popular at present; it provides information about, people, animals and items in transit. Among all identification technologies, barcode is the most

widely used for identification of items, because it has very low cost. It needs human intervention to scan each item individually. It's a time-consuming activity and may happen a chance of human error by missing of an item during scanning process. To overcome this problem an advance RFID auto-ID wireless technology is used to scan items automatically by radio frequency without human intervention [5]. Its further advantages are to scan multiple and moving items at once [6]. It also can scan in dirty and harsh environment. It can scan at longer distance, radio waves can passing inside human body and non-metallic materials. RFID tag has large data storage capacity. The efficiency is higher in terms of accuracy, speed, quality and flexibility of operation.

The objectives of supply chain management is to exploit customer value, minimizing cost and wastage to achieve a sustainable economic advantage by real-time flow of information with increased efficiency, speed, and accuracy [7]. The numbers of organizations make production, arrange distribution and selling several items. Organizations are exploring what is the provision of RFID to increase operating efficiency, product quality, cut-down inventory level, shrinkage and bullwhip effect also drive further income opportunities in supply chain [8]. Decreasing of tag cost has been widely recognized as the important aspect impelling the extensive usage of RFID technology [9]. The widespread implementation of RFID across the supply chain will bring substantial benefits leading to condensed operational costs and improved profits [10]. Numerous experts in financial matters suggested that it will happen in following basic areas.

i. Minimize inventory and shrinkage
ii. Reduce labor expenses in store, warehouse and on shop floor to get benefit.
iii. Minimize out-of-stock items
iv. Bullwhip effect

Various researchers and scientists believe that application of RFID technology would never be failed; if following issues are to be resolved.

i. Tag prices and efficiencies
ii. RFID standards must be harmonize,
iii. Interoperability throughout the supply chain
iv. Large volumes of data handle by IT infrastructure
v. Modification or variation of work and labor performs
vi. Cost of placement correctly shared
vii. Privacy matters

According to Alinean Research Company, the new developed RFID schemes could cut supply chain expenses by 3-5% and attain 2-7% increase in income. RFID provides accurate and instantaneous visibility of entities in the supply chain. It can make every project as sustainable to get benefits on long-term basis. Usually, 90% of plans need a official business case validation in order to get approval of projects. RFID wireless technology gives promise of bottom-line positive business benefits and a tangible Return of Investment (ROI) [11] as shown in Table 1.1.

Table 1.1: Tangible ROI (bottom-line positive business benefits) [11]

Overall project summary	Benefits
Total investment:	$17M
Net Present Value (NPV) of profits:	$26M
Scheme time span:	3 years
ROI:	188%
Payback period:	11 months

The main issue in the supply chain control is the product loss or shrinkage. The shrinkage is the variation between documented and actual inventory [12]. The loss of inventory is caused by some factors, including shoplifting, employee theft, vendor fraud, administrative error and breaking in transit or in store and cashier mistakes that advantage to the customer. As per record of National Retail Security Investigation led by the University of Florida, reduction in the United States during 2009 denoted 1.44% of retail sales [13]. This fraction is amounting to the billions of dollars is missing in record each year for U.S. retailers only. Therefore, security services including guards, tags, and cameras are used by retailers as an exertion to reduce shrinkage. Radio-Frequency Identification (RFID) as an evolving technology has produced tremendous amount of interest in the supply chain domain to reduce the loss. RFID technology has been used to provide more effective way to identify and track items at the several stages throughout the supply chain in huge retail industry.

3. RADIO FREQUENCY IDENTIFICATION (RFID) TECHNOLOGY:

Radio frequency identification (RFID) is a wireless technology. It is used for spontaneously tracking, locating or identifying and data capture of items by radio frequency waves with no line of sight in real time picture of business operations in an indoor environment. RFID works on radio wave frequencies according to the necessity such as LF, HF, UHF, and Microwave. The RFID system has three basic components. 1) RFID tag (data carrying device), 2) RFID reader (transceiver) and 3) middleware as shown Fig 1.3.

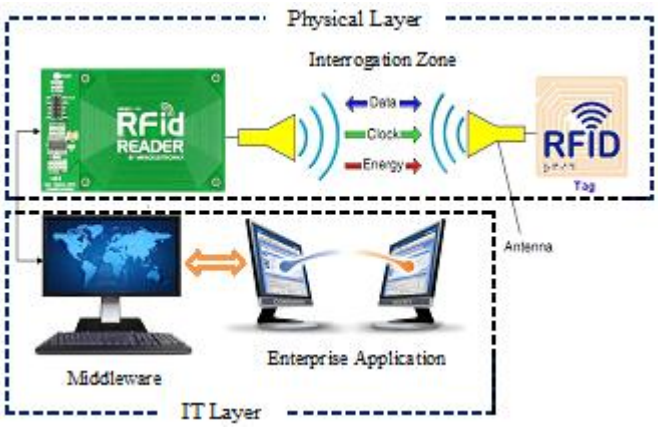

Fig.1.3. Typical RFID System [16]

The working principle begins when RFID reader transmits radio frequency wave signal to the tagged items, which contains the microchip (data storage device). Each tag has a unique identification code number and may optionally hold additional information about the object. When it receives the radio wave signal, immediately activates and send response back radio wave signal along with data towards RFID interrogator. The captured data sends to the middleware, which filters and sort the data and send important information to the main business software to monitor and control the SCM [14]. It provides real-time information of each item in SCM at various stages [15].

There are various application areas of RFID including manufacturing, logistics, asset tracking, retailing, warehousing, healthcare, and SCM etc.

3.1 RFID TAG:

The basic function of RFID tag is to identify the item similar to the barcode tag. RFID tag comprises of an antenna and an integrated circuit called microchip, which is used for sending a response back to the reader. It stores items data or other characteristics of object for identification purpose e.g TAG = [Type of product | Subtype | Product-ID | Position | Date | Size | Color | Price] [16]. There are various types of tags in shape and size according to different application areas are shown in Fig 1.4. It can be assembled into basic categories such as power source, memory type, operating frequencies, functionality, protocol, energy transfer and communication as shown in Table 1.2. It may be active (powered by battery) or passive (unpowered and reactively propagating a radio wave frequency signal) [17].

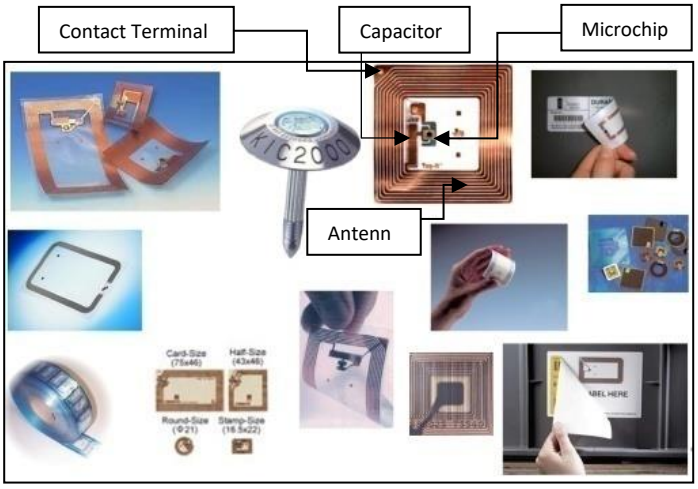

Fig. 1.4. Various RFID Tags [16]

TABLE 1.2 Classification of RFID tags [5]

Type of tag	Power usage
Passive	Power receiving from RFID reader called as 'reflective powered'. It is small and virtually unlimited life span.
Semi-passive	Battery is used as a power source to retain memory in the tag and to modulate the reflected signal.
Active	Power received by an internal battery, read range is greater and more expensive than passive tags due to read & write provision. Batteries are periodically replaced

Memory type	**Application**	
Read-only	Memory is programmed by factory once manufactured can't be modified. Limited data can store commonly 96 bits of information	
Read-write	Read and write provision. Store larger data from 32 kb to 128 kb, more expensive than read-only chips, used only for tracking expensive items	
Frequency	**Range**	
LF	125 kHz -134 kHz, generally tags are passive, have short read ranges of few inches	
HF	13.56 MHz, passive tags use near field inductive coupling, read range is about 3 ft	
UHF	433 MHz (active tags- read range 100 ft) or 860 MHz – 960 MHz (passive and semi-passive tags- read range about 20 ft)	
Microwave	2.4 GHz and 5.8 GHz frequency using ISM band. Read range of passive, semi-passive and active tags (15, 100, and 350 ft) respectively	
Class	**Functionality (EPC Global Classes)**	
Class 0	Passive tags during manufacture of IC chips having Write Once Read Many (WORM)	
Class 1	Passive tags with WORM chips, writing first time can be done at the factory or at site of operation	
Class 2	Passive tags, read/write capability in available memory for user and possibility of data encryption	
Class 3	Semi-passive tags with on-board environmental sensors, read/write capability, and memory space availability for user	
Class 4	Active tags onboard sensors having read/write capability, user memory, and provision for peer communication with other active tags and readers	
Class 5	Define reader which communicate and power the tags belonging up to the aforesaid classes	
Protocol	**Working Standard**	
Open Protocols	Developed by ISO 18000-6(A/B) and are available in equal terms globally for those who want to use them	**Air Interface Protocols** Decide how the tag data communicate using EM waves and include frequency of operation, emission levels, bit rate, anti- collision algorithms, modulation, encoding, and so on **Data Content Protocols** Division, definition, and layout of the memory in the IC, mandatory information that should be included there with their specific locations,
Proprietary Protocols	Developed by manufacturers for their own business purpose; e.g, Texas Instrument's, Alien, TI Tag-IT, Intermec, Intelli Tag.	
Energy Transfer	**Communication of tag and reader**	
Near field	Proximity electromagnetic, or inductive coupling. Generally, use LF and HF frequency bands	
Far field	Propagating electromagnetic waves called as Backscatter coupling. Operates on UHF and microwaves frequency bands	
Transmitter in Tag (Active Tag)	Battery powered having longer read range of operation as compared to passive tags. At powered ON it transmits 16 bit unique ID code on 433 MHz frequency at each 6 seconds. Transmission time is 100ms then goes to sleep for saving battery. After each	

	6 second it wakes up automatically and transmits its unique 16 bit code. It remains ON as long as the tag is powered ON. Battery life is 2 months with continuous on position.

The data of item stored into the tag memory as unique Electronic Product Code (EPC). It is used to signal back to the reader to identify the object to which the tag is attached. Tag can be attached to a pallet, case or item etc. The environmental sensors can be attached to the tag which measure environmental parameters like humidity and temperature. The sensors information may communicate with the integrated circuit, and then sends to RFID reader.

3.2 RFID READER:

RFID reader communicates with tags in the interrogation zone between reader and tag. It consists one or more than one antennas and the interrogator circuitry (IC). Antenna is used to transmit or receive radio wave signal along with the data to/from the tag to identify the object. The interrogator circuit is a transition among the reader antenna and IT layer. Reader circuit is used to send and receive data by the reader antenna and then sending back end for processing. It also coordinates between different reader's antennas for the efficient reading of tags. RFID readers are categorized according to the design, power supply, communication, mobility, protocol, frequency spectrum and data encoding protocol as shown in Table 1.3.

Table 1.3: Classification of RFID readers [18]

Type	**Application**
Design	
Read	Reads data from the tag.
Read/write	Reads data from the tag and writes on the tag
Power supply	
From Network	Get power from external source by using power cord, mostly stationary readers. Power supply range (5V to 12V and 24V).
Battery Assisted	Portable, light weight, battery power supply to the motherboard. Both handheld and stationary, use 5V to 12V for power supply.
Communication Interface	
Serial	Connected to host computers for using serial communication link by RS-485, RS-232, USB or IC2; limited no. of serial ports at host computer, low data transfer than network readers.
Network	Associated to host computer by wire or wireless, it supports multiple network protocols (Ethernet, TCP/IP, UDP/IP, HTTP, LAN, WLAN, and others) as a network device, large number of readers can connect small number of computers
Mobility	
Stationary	Fixed at the walls, portals, entrance and exit gate etc. Power supply range (12V to 24V), weight 1.5 kg to 5 kg, reading range up to 300 m
Mobile	Reader is a handy, moveable device have built-in antennas, battery powered, light weight (82-700g), reading range up to 100m, working wirelessly having memory block to save data and then transfer data in

	the database via wire. It can integrate with barcode scanner for both tag and barcode identification
Interrogation protocol	
Passive	Limited to only "listening and data transmission techniques called transponder-driven protocols for communication
Active	According communication protocols number of tags to be talked, it is more capable and faster than passive
Frequency spectrum	
Non-unique	Two Radio frequencies used by the reader for fast, reliable and full-duplex communication
Unique	unique frequency range is used (short bandwidth <80 MHz) for both transmission and reception
Data encoding protocol	
Simple	Unique protocol is used for data transmission between tags and the reader
Agile	Multiple protocols is used for data transmission between tags and readers include EPC Gen1, EPC Gen2, ISO 18000, and TIRIS Bus Protocol

3.3 MIDDLEWARE:

It is the physical network may be wired and or wireless that sends and collects data directly from the interrogator. It performs a business-related process regarding the data which carries, store and sends to the enterprise applications as needed. It is the intermediate between the interrogator and the enterprise application [18].

3.4 ENTERPRISE APPLICATION:

The enterprise application is the process of data collection from middleware using IoT and used in relevant business processes, depending on the business process involved. It is the special designed software used for various features of a firm's operations including purchase, inventory control, manufacturing, human resources, marketing, sales and resource planning [19]. In this application selection of RFID devices such as tags, readers and middleware for particular application is very important. The selection criteria depend upon protocol, electromagnetic power, read range, frequency, shape, and size of the tags and so on. Interoperability of the different components in a single system as well as between different systems is very important in business process operating globally. Interoperability, quality, privacy and safety depend upon standard. Standard is well-defined set of instructions to follow throughout the world for any specific operation. RFID technology is working on ISO and EPC global standard, where each and every aspect of the system and its working are well-defined. ISO and EPC global standard is regulated by the authorities such as Federal Communication Commission (FCC) (USA), European Radiocommunications Office (ERO) (Europe), Australian Communication Authority (Australia), and so on. The responsibility of all above-mentioned authorities to confirm that the standard to be followed properly.

The supply chain management sustainability can be controlled by proper management practices throughout the lifecycles of products using enterprise application. The objective of supply chain sustainability is a long-term planning including economic, social and environmental aspects of production management. This objective can be achieved by real-time exchange of information using

RFID system. This system has provision to integrate with the Xbee wireless network to enhance the communication range.

4. XBEE (ZIGBEE) WIRELESS MESH NETWORK:

Xbee wireless devices are designed for less power eating, low data flow, least cost, low latency, high level of security and less complicate than those from present offered standards. It is simple to use and easy to configure having longer battery life and is able to self-healing and self-organizing large network. It is highly reliable in both normal and harsh environments [20-21]. ZigBee is built on IEEE 802.15.4 standard and firmly follows rules to confirm abiding sustainability and consistent operation. It is regulated by ZigBee Alliance. ZigBee Alliance defines additional stack layers including (PHY, MAC and NWK layer) which are based on the (7- layer) Open Systems Interconnection Reference Model (OSI/RM). Zigbee works on 2.4GHz unlicensed Industrial Scientific and Medical (ISM) band [22].

The economic cost permits the technology to be widely used in wireless control and monitoring applications, use low power permits longer battery life and the mesh networking provides high consistency and longer transmission range.

In multi-hop wireless mesh networks, one or more intermediate nodes available along the path that receive and forward packets via wireless links. Multi-hop wireless networks have numerous benefits associated to networks with single wireless links. Multi-hop wireless networks can extend the exposure of a network and improve connectivity. Multiple “short” links might require less transmission power which reduce energy consumption than over “long” links. It enables higher data rates resulting in higher throughput and more efficient use of the wireless medium. Multi-hop wireless networks avoid wide placement of cables in a cost-efficient way. In case of dense multi-hop networks having number of paths might become available that can be used to increase robustness of the network.

Wireless communication technologies generally operates on frequency bands to share information with several users at different Radio Frequency (RF) schemes. Specifically, WiFi, Bluetooth and currently Zigbee technologies are used to extend the communication range of the RFID reader as shown in Table 1.4.

Table 1.4: Comparison of wireless technologies [5]

Characteristics	ZigBee (WPAN)	Wi-Fi (802.11) (WLAN)	Blue Tooth (WLAN/WPAN)
IEEE Specification	802.15.4	802.11 a/b/g/n	802.15.1
Industry Organizations	ZigBee Alliance	Wi-Fi Alliance	Bluetooth SIG (Special Interest Group)
Data Rate	20,40 and 250 Kbps	2 to 200Mbps	24Mbps
Range (meters)	1-300	1-100	1-10
Frequency	868MHz, 900-928MHz, 2.4GHz	2.4 & 5 GHz	2.4GHz
Complexity	Low (simple)	High (very complex)	High (complex)
Battery life (days)	100-7000	1-5	1-7
Establishment segment speed	30 msec	3 sec	10 sec
Power Consumption	~ 1 mW	~ 160 mW – 600W	~ 40 -100 mW
Cost ($ US)	~ 2-5	~ 20-50	~ 4-5
Nodes per network	255/65000+	30	7
Topology	Star, Tree, Mesh	Tree	Tree
Standby Current	3 x 10 -6 amps	20 x 10 -3 amps	200 x 10 -6 amps
Memory	32-60KB	100KB	100KB
Security	128 bit AES and key define	SSID	64bit, 128bit
Spreading	DSSS	DSSS, CCK, OFDM	FHSS
Protocol Stack Size	4"32KB	100+KB	~100+KB
Strong hold	Long battery life, low cost, low data rate	High data rate	Interoperability, cable replacement
Applications Focus	(Monitoring & Control) Remote control, battery-operated products, sensors	(Web, Email, Video) Internet browsing, PC networking, file transfers	(Cable replacement) Wireless USB, handset, headset

5. RESEARCH AIMS:

To optimize the business within available resources in Supply Chain Management by achieving sustainable competitive advantage.

6. RESEARCH APPROACH:

Step1: Attach RFID tags with each item for tracking and updating the information of items characteristics in the tags memory.
Step2: Deploy RFID readers at each section depending upon the planned area according to business requirement as shown in Fig 1.5.
Step3: Configure one Xbee device as coordinator and attach with the computer using Ethernet interface link to LAN.
Step4: Configure number of routers as well as end nodes (module) then remotely attach with large number of active RFID readers system based on multi-hop placement using dual radio frequency to overcome the range of radio areas to capture information from the RFID readers and drive it to the main server through coordinator and intermediate routers.
Step5: Attach wireless sensors with RFID tags wherever required to monitor the parameters like temperature, light, and humidity etc.
Step6: The established RFID-WSN system has provision to communicate to the main server by ZigBee network.
This system is able to provide real-time identification of item's characteristics and environmental parameters at single control platform, which can enhance the overall efficacy of supply chain.

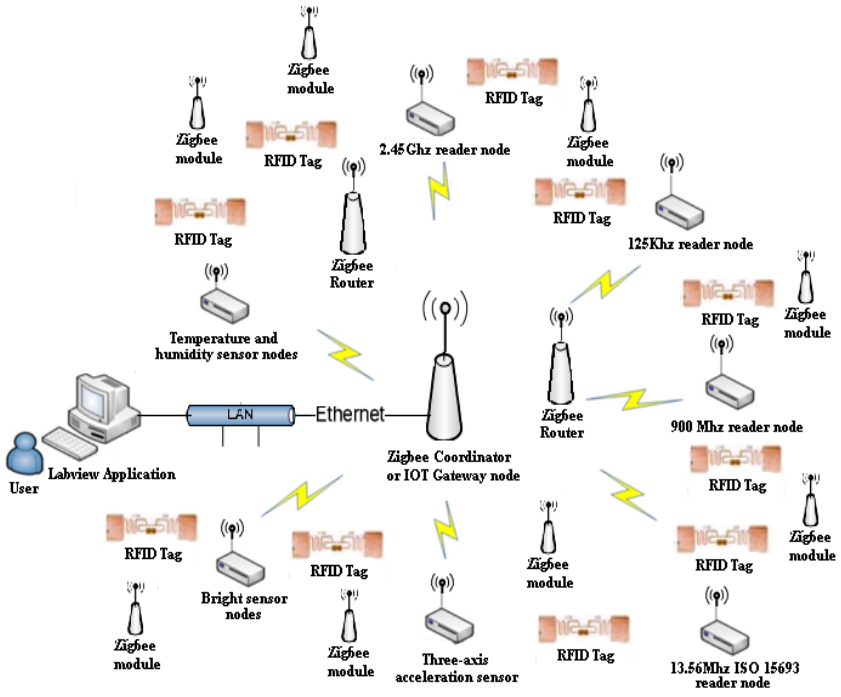

Fig. 1.5. IOT system architecture [6]

This system can be applicable for sustainable manufacturing, supply chain management, car parking, office automation and supermarket for item pricing. This system can be modified according to the need-based approach. The benefit of this system is to provide visibility of items at a single control

platform. That visible picture offered by system could guide to shrink losses in terms of wastage of time expenditure and services. It also can lower inventory levels, distribution and handling costs. Integrated system permits items to be scanned on real-time basis through the supply chain providing accurate and complete information of all items with greater efficiency. Inventory visibility provide gains in areas such as quick response to consumer demands and market tendencies. Now it is easy to decide to make provision right product in the right place at the right time.

7. SUMMARY:

Integrated RFID-WSN and Xbee wireless network system has significant potential of tracking of items identification and data capture on real time basis. It also measures the environmental parameters. Xbee devices have great provision to increase the range of data transmission of RFID readers to main business software by multi-hop communication. The main business software is worked on LabVIEW GUI which can provide visibility of items at each stage of supply chain on a single control platform. The advantage of this system is to lessen human error, minimizes wastage in terms of energy, expenditure, time, out of stock inventory and services. It also improves productivity and information accuracy at indoor environment of sustainable advantage.
The above system can be integrated with Global Positioning System (GPS) for future work, which can monitor both indoor as well as outdoor real time information.

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